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## The silhouette of the mandibular condyle on radiographs.

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# Summary

### 1. Introduction

The review of the literature indicates that numerous imaging techniques of the TMJ exist, all with their specific limitations. Reliability, reproducibility and accuracy of conventional radiographic projections have been investigated by several authors. Few studies concentrate on the shape of the condyle on the radiograph and on the relationship between the gross anatomy, condylar inclination and the radiographic projection on the type of image.

### 2. Aim, objectives of the study and problem formulation

The aim of the study is to assess the reliability of the determination of the contour of the human condyle on infracranial Parma radiographs and on panoramic tomograms (OPG) as used in the Groningen longitudinal study of the temporomandibular joint.

The specific aims of the investigations are:

- ◆ How can the condylar silhouette on the radiograph be quantified?
- ◆ Is it possible to classify the condylar silhouette on radiographs?
- ◆ If so, how accurate, robust and reproducible are these classes on the radiographs?
- ◆ Do the infracranial projection and the panoramic X-ray radiography depict the condylar silhouette in a reproducible way, and can we use one classification system for the different projections?
- ◆ Do these different radiographic projections produce identical or different condylar silhouettes on radiographs?
- ◆ Which is the relationship between the anatomy and inclination of the condyle and its silhouette on the radiograph?

### 3. Material

The material used for this study consisted of a series of 152 dry mandibles and of a collection of doubly taken infracranial radiographs already made before as a part of a longitudinal follow up study of 172 patients. These patients have been treated at the orthodontic department of the University of Groningen and have participated in the Groningen longitudinal growth study.

The dry mandibles were selected from a large collection of macerated skulls and mandibles present at the orthodontic department of the University of Groningen. They were selected on undamaged condyles and a fairly intact dentition. The mandibles showed no obvious pathological conditions.

### 4. Radiographic methods

A review of the history, development and a technical description about the infracranial Parma II, III and Parma IV radiograph and the panoramic radiograph (OPG) are described in this chapter.

The subsequent major changes and modifications to the Parma projection in Groningen, based on the original Parma I projection, in the period 1950 until 1990, will be identified by the Parma II, Parma III and Parma IV projection respectively.

To express the total risk of the irradiation, used with the different projections, the mean organ dose must be used to calculate the effective dose equivalent according to Kuijl van der (1992). Since no data were available concerning the results of the effective dose equivalent with Parma II radiographs, the results of a comparable study at the University of Amsterdam (Stelt van der et al, 1987) were used in addition to the data published by Kuijl van der (1992) about the Parma IV projection. A careful interpolation to the Parma II radiograph was made by Kuijl van der and Stelt van der (pers. comm.). It was concluded that the Parma IV radiograph generates 4 times less radiation than the Parma II radiograph.

## 5. The condylar silhouette

In this chapter a classification system for the condylar silhouette in itself was described, which, not related to an anatomic form, was based on infracranial radiographs from the Groningen longitudinal study. Using an acetate sheet on which an Y- and X-axis are drawn, which is laid over the radiograph with the Y-axis parallel to the posterior border of the condylar neck and the X-axis passing through the broadest point, all forms of the different condyles could be classified in one of the 8 classes in fig. 6.

The **0-class** is characterized by a spiky and condylar silhouette. Based on clinical experience the 0-class was added to the classification.

The **1-class** is characterized by a vertically elongated silhouette, with a steep slope of the anterior contour. There exists a greater height to width ratio. The vertex is situated left of the horizontal midpoint.

The **2-class** has an equal height to width ratio, the vertex is situated left of the horizontal midpoint.

The **3-class** is broad and relatively low. There exists a height to width ratio less than 1. The vertex is situated left of the horizontal midpoint.

The **4-class** has a somewhat symmetrical and mostly rounded silhouette. The contour can be round or symmetrically flattened with the vertex situated halfway the X-axis.

The **5-class** is characterized by a squared or rectangular appearance of the condylar silhouette and has a flattened superior surface, almost parallel to the X-axis and without a clearly defined vertex. The dorsal and ventral contours run more or less parallel to each other.

The **6-class** has its vertex over the middle of the X-axis and often the superior part of the ramus and the condylar neck are already curved anteriorly. It is "wave" shaped. There exists a height to width ratio less than 1.

The **7-class** covers all forms which do not fit in the afore mentioned classes, including condylar projections of a strange form. These oddly shaped silhouettes are considered as a separate 7-class.

## 6. Reproducibility of the classification of the condylar silhouette on the infracranial radiograph of dry mandibles

298 infracranial radiographs, made from dry mandibles, were classified twice in random order by two judges until consensus was reached. The measurement of the amount of agreement was calculated using Cohen's kappa statistic. It turned out that our classification for the condylar silhouette offered a reproducible method to describe the two dimensional projection of the condyle directly from the radiograph. The kappa value of 0.74 indicates that the results can be considered as "good". Eighty four percent of the radiographs were scored identically.

The clinical value of this classification resides in its relative easiness to describe the silhouette of the condyle on the radiograph, without using complex measurements allowing easy and exact clinical communication. According to the two observers, the classification can be easily mastered and does not require a long clinical experience. It is an entity of its own and does not describe the real anatomic form of the condyle nor does it indicate normal, deformations or pathology, it is just a descriptive item. It is furthermore independent of size and thus independent of radiological enlargement.

## 7. Robustness of the classification of the condylar silhouette on the infracranial radiograph of dry mandibles

Alterations of the X-ray beam inclination or small changes in positioning theoretically may cause changes of the shape of the bone projected on a radiograph. According to the literature, there is a great tolerance with regard to form distortion before it becomes of clinical importance. Thirteen mandibles, from which the right condyle represented the 1-, 2-, 3-, 4-, 5-, and the 6-class on infracranial radiographs were radiographed in a specially designed construction, allowing three dimensional adjustment of the mandibles towards the X-ray source (fig. 8). Changes of plus or minus 3 degrees resulted in 86% identical classifications for the condylar silhouette. Within changes of plus or minus 6 degrees, 77% was classified identical (figs. 10 through 15). No randomly located different classes showed up within the diagrams indicating the robustness of the classification. It has not been possible to create a 7-class condylar silhouette just by changing the position of the mandible which at first showed a "normally" shaped condylar contour, not even with off-centers of 12 degrees. This means that the 7-class is not just a strange formed condylar silhouette because a relative normal condyle happened to be incorrectly projected but an entity of its own. Changes of 6 degrees are comparable to



a displacement of the X-ray tube of approximately 16 mm. A trained roentgenological technician may be expected to adjust the X-ray tube always amply within this range.

## **8. Method error of the Parma II, III, IV radiographs and of the OPG**

The method error of the Parma II (and III) was tested in two different ways:

- ◆ using dry mandibles and
- ◆ using a collection of double made Parma II radiographs from patients as a part of the Groningen longitudinal study.

The dry mandibles were radiographed using a special construction (figs. 18 and 19), allowing accurate adjustment according to the specifications used for patients. The horizontal and vertical positioning of the mandibles both covered a wide range indicating the large variety in mandibular form. Asymmetry between right and left side of the same mandible in adjustment towards the central X-ray beam occurred frequently.

Sixty four percent of the mandibles had a different combined horizontal and vertical positioning of more than plus or minus 2.5 degrees.

In contrast to this variation, the analysis of variance showed more or less identical mean-positioning values for the different condylar silhouette groups. This means that the form of the mandible does not systematically lead to specific condylar silhouettes.

The reproducibility of the (double) Parma II radiographs made from patients resulted in a kappa value of 0.71 and 88% of identical scoring.

◆ Method error of the Parma IV radiograph: Due to the exact positioning of the mandibles, the Parma IV has a high degree of reproducibility. One dry mandible was radiographed five times; the condylar silhouettes were identically classified.

◆ Method error of the OPG: A specially designed craniostat was used to make OPG's from dry mandibles, provided with metal implants at Gonion and the highest point of the coronoid process.

The reliability of the positioning was established and the influence of canting and/or translation of the mandibles on its condylar silhouette was investigated. The mandibles were radiographed in an individualized position simulating the same situation as when a patient would have been radiographed (figs. 20 and 21). The condylar silhouette was classified on the OPG's. Although it sometimes looked smaller or broader on the provoked tomograms, the condylar silhouette was constant in its relative shape.

It has been demonstrated that there is a great tolerance against form distortion, which in turn is of clinical significance. In the posterior parts of the jaws the structures may be displaced at a considerable distance without producing form distortion of the condylar projection. Careful positioning of the patient in the cephalostat consequently will result in tomograms on which the silhouette of the condyle can be classified in a reproducible way.

## **9. The condylar silhouette on the infracranial radiographs (dry mandibles)**

Radiographs according to the Parma II and the Parma IV projection were made from mandibles. The radiographs were classified according to the 8-point classification and the frequency distribution of the condylar silhouette types was computed.

The Parma II projection has a tendency for the 3-class (52%), the 4-class (23%) and the 2-class (10%). The Parma IV projection has a tendency for the 4-class (39%), the 3-class (35%) and the 6-class (14%). The Parma II and the Parma IV projection did not always depict the condyle identically. This diversity is probably due to differences in geometry between both projections. The Parma IV projection had a tendency to depict the condyles somewhat lower and rounder.

## **10. The condylar silhouette on the OPG (dry mandibles)**

OPG's of 152 dry mandibles were made using the same specifications and craniostat as described in chapter 8. The condylar silhouette was classified and the frequency distribution of the different class types was computed. The OPG had a tendency to depict the condyles as 4- and 6- classes, which consisted of 71% of the mandibles. Forty two percent of the OPG's were classified as a 4-class and 29% were classified as a 6-class. Only two condyles were classified as a 2-class. The 3-class constituted a relatively small percentage of the total. The silhouette of the condyle on the OPG was in majority a symmetric round (4-class) to an asymmetrical oval form, where the position of the highest point has a tendency to deviate to the ventral side on the film (6-class).

## 11. The association between the condylar anatomy and the condylar silhouette

A classification system, which came out of a combination of existing anatomic classifications for the human condyle, presented by Yale (1966, 1969) (fig. 22), Öberg et al. (1971) (fig. 23) and Solberg et al. (1985) (fig. 24) was developed, using 152 dry mandibles. The condyle is divided into three areas, an anterior part and posterior part as seen from above, perpendicular to the mandibular plane, and a superior part of the condyle as seen from behind, perpendicular to the posterior border.

The **superior surface**, observed from dorsal, was classified as: (fig. 25) type 1: flat, type 2: the top laterally, type 3: the top medially, type 4: rounded, and type X: other shapes.

The cranial aspect of the condyle has been divided into an **anterior** and a **posterior surface**, separated from each other by the long axis of the condyle (fig. 26). Observed from superior, they were classified as: type A: flat, type B: concave, type C: the most anterior c.q. posterior point laterally, type D: the most anterior c.q. posterior point medially, type E: convex, and type X: other shapes.

The method error was tested by classifying the 152 mandibles two times. There were no marked differences between the right and the left side condyles regarding their frequencies. Cohens's kappa resulted in an average kappa of 0.60 for the right condyles and 0.72 for the left side condyles. It turned out that the anatomic classification presented is an acceptable method to describe the shape of the human condyle on dry skull material.

The anatomy of the left and right condylar surfaces of the dry mandibles were classified with the anatomic classification (tabs. 11.8 through 11.13). Evaluation of the shape of the condyle in the study showed no consistent agreement with the results reported by Yale et al. Type A (fig. 26) with a flat surface occurred in 26% in Yale's study and in 20% for the adults and 8% for the age group of 0 - 19 years in Öberg's study. In our study however, this corresponded to type 1 and occurred in 4% of the total only. Type C (fig. 26), the angled type, was represented in 12% in Yale's study. The inverted V-shape described by Öberg occurred in 11% only in adults (fig. 23). This corresponds to type 2 and 3 of our study which occurred in 23% of the mandibles. From the left condyles 61% of the superior surfaces were classified a 4. From the anterior surfaces 37% was classified an E. Sixty two percent of the posterior surfaces were classified a D.

From the right condyles 73% of the superior surfaces were classified a 4. From the anterior surfaces 35% was classified an E. Eighty two percent of the posterior surfaces were classified a D.

Symmetry between right and left side occurred for the superior surface in 101 mandibles (68%); for the anterior surface in 60 mandibles (40%) and for the posterior surface in 104 mandibles (70%). Symmetry of all the three surfaces occurred only for 4 mandibles (3%).

The association between the condylar surface and the silhouette of the condyle on the Parma II, Parma IV and the OPG was investigated using contingency tables of the condylar silhouette and the condylar surface shape. Although there were small differences between the right and the left side for each radiographic projection, the results for the Parma II and the Parma IV were comparable.

It was shown that all the different parts of the condylar surface contributed equally to a particular image on the radiograph. It was not evident which parts of the condylar shapes were responsible for a specific condylar silhouette type on the radiograph.

## 12. The association between the condylar axis and the condylar silhouette

The condylar axis can be measured into a horizontal inclination or alpha angle, and a vertical inclination or beta angle (fig. 28). It was found in our study that most of the mandibles were asymmetric in this sense that the condylar inclination differed often by several degrees between the right and left side. The method of measuring the condylar axis in an alpha inclination and a beta inclination proved to be accurate within a standard deviation of 0.8 degrees. There was a wide range in the condylar axial position for both the alpha inclination and the beta inclination.

The association between the condylar silhouette and the condylar axis on the Parma II and IV radiograph and on the OPG was investigated using analysis of variance. There were no significant differences between the results for the right and left side for the three radiographic projections. The alpha and beta inclination were significantly associated to the silhouette of the condyle on the Parma II and Parma IV radiograph, and on the OPG (with exception of the left side OPG alpha angle). Contrary to Berry's study (1960), our findings indicated that there was a relationship between the condylar inclination and its radiographic silhouette. These differences may probably be accounted to the low number of observations (only 24 right condyles) in Berry's study.



### 13. Comparison of the silhouette on the Parma II radiograph, the Parma IV radiograph and the OPG

The condylar silhouette classified on the Parma II and Parma IV radiograph and the OPG made from the same dry mandibles were compared with each other.

Due to the differences in geometry it appeared that certain shapes tended to change from one silhouette class into another (figs. 31 and 32).

It was concluded that each projection creates its specific condylar silhouette. The difference in the direction of the central X-ray beam and the geometry of the three projections are not extreme so that we could expect to see the same range of different shapes of the condyles. Combining this with earlier results we conclude that the Parma II radiograph has the broadest range of condylar silhouette types, followed by the Parma IV, while the OPG has the smallest range.

The 2-class, and the 3-class occur more frequently on the Parma II radiograph, whereas on the Parma IV the 3-class and the 4-class occur more frequently and on the OPG the 4-class and the 6-class are more frequent. The 7-class occurs on the three types of radiographs in approximately the same frequency.

### 14. General discussion

The aim of this study is to assess the reliability of the determination of shape of the human condyle on panoramic tomographs (OPG) and on the infracranial Parma radiograph, as used in the Groningen longitudinal study of the temporomandibular joint.

The radiographic image is the result of an interplay of anatomical and geometrical variables. Since the projection obviously reflects both, it is concluded that the condylar silhouette contains important information. This information is made accessible in this study by means of an 8-point classification scale. This classification proved to be reliable and reproducible.

It has not been the intention of this study to define clinically what constitutes pathology of a condyle. Marked irregularities or lesions in the articular surface were excluded from this study.

Because of this selection criteria of an intact condylar surface no 0-class or 1-class were noted, this in contrast to findings in the Groningen longitudinal study where these classes were represented very clearly. The 0-class originally had a prevalence of less than 1% and gradually increased to 5% after 15 years (Dibbets and Weele van der, 1992). This also indicates that the collection of dry mandibles is not a representative sample.

In this study it is shown that the condylar silhouette on the infracranial Parma II, III and IV radiographs and the OPG can be classified in a reproducible way.

The Parma II radiograph displays the broadest range on the 8 point classification scale. In addition it has been shown that this radiograph is not very susceptible to artefacts. The combination of these properties make the Parma II radiograph a valuable clinical tool, which might be expected to detect subtle differences more readily than both other projections. Because this projection was widely used 15 to 20 years ago most references are from that period.

However, the Parma IV projection generates considerably less radiation than the Parma II projection with respectively a total  $H_{\text{eff}}$  of 0.03 mSv. versus a  $H_{\text{eff}}$  ranging between 0.11 mSv. and 0.12 mSv. for the Parma II. For this reason the Parma II projection should not be used anymore for a newly to start project.

The OPG displays a smaller range of condylar silhouette types. This is due to the fact that the medial and lateral pole are sometimes not included in the X-ray slice which is cut through the condyle. The condylar silhouette on the OPG is the depiction of the contour of this slice.

The results of this study also indicate that there is a significant association between the anatomy of the condyle and its condylar silhouette on the radiograph. This is only the case for the condylar axis, whereas the surface of the condyle does not significantly contribute to the condylar silhouette.

An explanation for this lays in the fact that mostly the central X-ray does not hit the condyle to be radiographed along its long-axis. The medial and lateral pole largely contribute to the specific condylar silhouette.

Further research in temporomandibular joint dysfunction studies or in methodological studies on radiographic projections has to be done using the 8-point classification system on radiographs and combining these results with other data such as pain, clicking, growth type etc. and to establish possible clinical relevance. If necessary the classification can be adjusted to pathological forms (Boering, 1966; Leeuw de, 1994).

The radiographs made within the framework of the Groningen longitudinal study are now ready to be further analyzed with the help of the results of this study.